Air Quality Monitoring

at

Harrison Court, Butte, Alaska

1999 – 2010

February 2, 2011

Air Quality Division

Air Monitoring
&
Quality Assurance
Program

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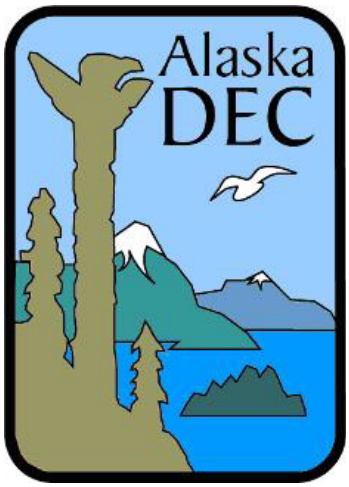

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Introduction

The Alaska State Legislature has mandated the Alaska Department of Environmental Conservation (ADEC) to assess, evaluate, and mediate environmental issues that may affect the health and welfare of residents within the state (Title 46 of the Alaska Statutes). ADEC established and maintains a statewide network of regulatory and special purpose monitoring sites that collects ambient air data used to assess the air quality within the state. The network currently comprises sites in Juneau, Anchorage, Fairbanks, and the Matanuska- Susitna (Mat-Su) Valley as well as additional, special purpose or temporary sites. This document gives background information on ambient air quality issues and reports on the air quality monitoring done at the Butte monitoring site, one of the three sites in the Mat-Su Valley.

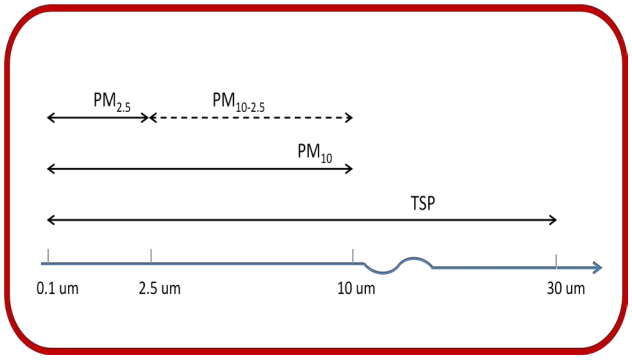
Background

The earth's atmosphere is a complex mix of gases, vapors, and particles. Particles in the atmosphere are a mixture of solid and liquid molecules. They can be nuclei around which vapors condense, can stick together and form larger particles, and may react chemically with other substances in the atmosphere to form different compounds. If particles suspended in the air get large enough, they fall to the ground. Those particles that remain suspended in the air are referred to as particulates.

Particulates can be classified by their chemical attributes but are commonly classified by their physical attributes. Different sized particles behave differently in the atmosphere and have different human health and environmental effects. Therefore, scientists find it useful to classify particulates according to size. The size definition most useful is one that directly relates to how particulates behave in air and the two properties that most influence behavior are shape and density.

Scientists have developed the term "aerodynamic diameter" that unites both shape and density in a single dimension. The aerodynamic diameter is the diameter of a spherical particle having a density of one gram per cubic centimeter (g/cm^3) and the same terminal settling velocity in the air as the particle of interest. A solid sphere, a hollow sphere, and an irregular shaped particle having different densities and different shapes can have the same aerodynamic diameter. Conversely, visually similar particles can have different aerodynamic diameters.

EPA regulates and tests for different size classes of particulates based on this definition. The EPA regulatory categories are: total suspended particulate matter (TSP), PM_{10}, $PM_{2.5}$, particles less than 0.1 μm, and condensable particulate matter. Of these five categories, this report will deal with TSP, PM_{10}, and $PM_{2.5.}$



TSP refers to airborne particles having an aerodynamic diameter between 0.1 and 30 micrometers (µm)[1]. This category encompasses a broad size range and was the only size fraction monitored in the 1970s and 1980s. As new technology produced samplers that could better separate the size fractions, the EPA revised its regulations. PM_{10} is particulate matter having an aerodynamic diameter less than or equal to 10 micrometers (µm) and often consists of common crustal materials. $PM_{2.5}$ is particulate matter having an aerodynamic diameter of equal to or less than 2.5 µm. It is usually associated with smoke or other combustion products. $PM_{10-2.5}$ is a recent monitoring development that further differentiates PM_{10} from $PM_{2.5}$ and represents the fraction of particles in the size range between 2.5 µm and 10 µm.

Particle size relates directly to its potential adverse health effects: the smaller the particle, the greater the potential. Particles having an aerodynamic diameter greater than 10 µm primarily lodge in the oral and nasal passages. (The average human hair has a diameter of 60 µm.) These particles are largely eliminated by natural body processes and do not penetrate farther into the respiratory tract.

Particulates can travel deep into the respiratory tract and may lodge in the lungs. Major concerns for human health from exposure to PM_{10} include effects on breathing and respiratory systems, damage to lung tissue, cancer, and premature death. The elderly, children, and people with chronic lung disease, influenza, or asthma, are especially sensitive to the effects of particulate matter. Acidic particulates can also damage human-made materials and is a major cause of reduced visibility in many parts of the U.S.

$PM_{2.5}$ particles can lodge in the very small air sacs of the lungs, the alveoli. These particulates slow the transfer of oxygen and carbon dioxide and cause the heart to work harder to achieve the same rate of transfer. This effect is most noticeable in children and the elderly as well as people with respiratory diseases like bronchitis, asthma, emphysema, or heart problems. However, particulate inhalation can affect all people and adverse effects may only appear after repeated low concentration exposures or exposure to extremely high concentrations. $PM_{2.5}$ particulates may contain carcinogens and other harmful substances.

PM_{10} often consists of common crustal materials such as dust from roads as well as volcanic ash. $PM_{2.5}$ generally comes from combustion processes like industrial stack emissions, motor vehicles, wood smoke from forest fires or home heating, and chemical processes that emit gases containing sulfur dioxide and other volatile organic compounds. $PM_{2.5}$ can also form when pollutant gases combine in the atmosphere. Natural sources of suspended particulates include

[1] A micrometer is a millionth of a meter.

volcanoes (ash), glaciers (silt), unpaved roads and non-vegetated land (windblown dust), and forest and grass fires (ash). These natural sources contribute both fine and coarse particles to ambient air. Anthropogenic sources include industrial processes, mining, vehicles, and home heating.

Monitoring

ADEC samples airborne particulates with special filters in instruments that operate at specified flow rates for specified times. Current PM_{10} and $PM_{2.5}$ samplers employ either Teflon or glass fiber filters. The FRM Partisol 2000 method[2] collects a sample by continuously pumping ambient air through a size selective inlet and a pre-weighed Teflon filter for 24 hours. ADEC staff collects the filters, weighs them, and uses the difference between the filter weights along with flow rate, flow duration, ambient temperature, and ambient barometric pressure to calculate concentration. ADEC programs these samplers to run on the national EPA schedule and typically samples every sixth day.

ADEC also employs an automated FEM method [3], which uses a glass-fiber filter tape that lasts for several weeks. This sampler draws ambient air through a size selective inlet every hour. The sampler measures the amount of beta radiation that passes through the tape and uses that data to calculate the mass of the sample. It also uses the flow rate, flow duration, ambient temperature, and ambient barometric pressure to calculate a concentration.

ADEC does Quality Assurance (QA) checks of the data before uploading them to EPA's national database of ambient air quality data, the Air Quality System (AQS). EPA restricts direct AQS access to those in federal, state, local, and tribal agencies who load data into the database or use data from the database for analysis. EPA provides public access to these data via its AirData web application[4].

ADEC and EPA use these data to determine whether the air quality of a locality meets the National Ambient Air Quality Standards (NAAQS) set by the EPA. A standard is a rule against which to measure or compare a parameter. Most standards set an upper bound to a parameter. EPA has two methods for determining compliance (or attainment) with ambient air quality standards: deterministic and probabilistic.

A deterministic method allows a certain (low) number of exceedances over a set time and specific number of valid samples. EPA uses this method to determine compliance with the 24-hour PM_{10} NAAQS of 150 micrograms per cubic meter ($\mu g/m^3$)[5] under standard conditions[6] of

[2] A Federal Reference Method (FRM) is one that EPA has accepted for comparison to the NAAQS by meeting certain design, precision, and bias (performance) specifications (40 CFR Part 58).
[3] A Federal Equivalent Method (FEM) is an EPA-approved method that can be used in place of an FRM. Both FRMs and FEMs go through rigorous testing prior to EPA approval.
[4] http://www.epa.gov/air/data/index.html
[5] A microgram (µg) is a millionth of a gram.
[6] Gas volume depends on temperature and pressure that vary from place to place. By using reference values of temperature and pressure i.e., "standard" temperature and pressure (STP), one can compare different gas concentrations (mass per volume) independent of the temperature and pressure observed at the time of the measurement. EPA defines STP as 25°C and 760 mm Hg.

temperature and pressure. An area complies with this NAAQS if it has no more than one exceedance per year of valid samples on a one-in-three day[7] schedule with a data capture rate of at least 75%.[8]

A probabilistic method allows for multiple exceedances as long as the distribution of sampled values is such that a set statistic is less than the NAAQS. This method makes compliance with the NAAQS less sensitive to extreme conditions that may not be typical of the local area. EPA uses this method to determine compliance with the $PM_{2.5}$ 24-hour NAAQS of 35 µg/m^3 under actual conditions of temperature and pressure. An area complies with the 24-hour NAAQS if the average of the 98th percentile values for three consecutive years is less than 35 µg/m^3 and with the annual NAAQS if the 3-year average of weighted annual means is less than 15 µg/m^3. Table 1 contains the standards for both PM_{10} and $PM_{2.5}$.[9]

EPA's probabilistic methods employ a statistic called the "design value." Design values can be calculated from the sample data, using modeling results, or be a count of the number of exceedances of a NAAQS. Design values change from year to year depending on meteorological conditions, pollutant levels, and unusual events.

Table1. PM_{10} and $PM_{2.5}$ NAAQS and compliance criteria

Pollutant	Standard	Period	D/P*	Compliance criteria
PM_{10}	150 µg/m^3	24 hours:	D	Not to be exceeded more than 1/year over 3 years given a 1/3 day sampling schedule
$PM_{2.5}$	35 µg/m^3	24 hours:	P	3-year average of 98th percentile of 24-hour concentrations
	15 µg/m^3	Annual:	P	3-year average of weighted annual mean concentrations

*D = Deterministic, P = Probabilistic

The EPA does have a process by which data arising from unusual or "exceptional" events can be excluded from the data set used to determine compliance with a standard. EPA introduced the exceptional events policy in 2007. As of December 31, 2010, ADEC has not requested an exceptional event exclusion for ambient air quality exceedances.

If an area cannot meet an air quality standard, the Clean Air Act may designate it as a "non-attainment" area. This designation triggers a five-year window during which the state must gather additional data, must submit a State Implementation Plan to the EPA, must institute control measures, and must meet the standard at the end of that time. EPA can levy sanctions against a designated non-attainment area that may result in loss of federal highway funding and of economic development opportunities.

[7] EPA specifies days throughout each year on which all federally referenced monitoring must take place. There are schedules that allow sampling once every three, six, or 12 days as well as daily.
[8] Refer to 40CFR Part 50 for detailed methodology.
[9] Refer to 40CFR Part 50 for detailed methodology.

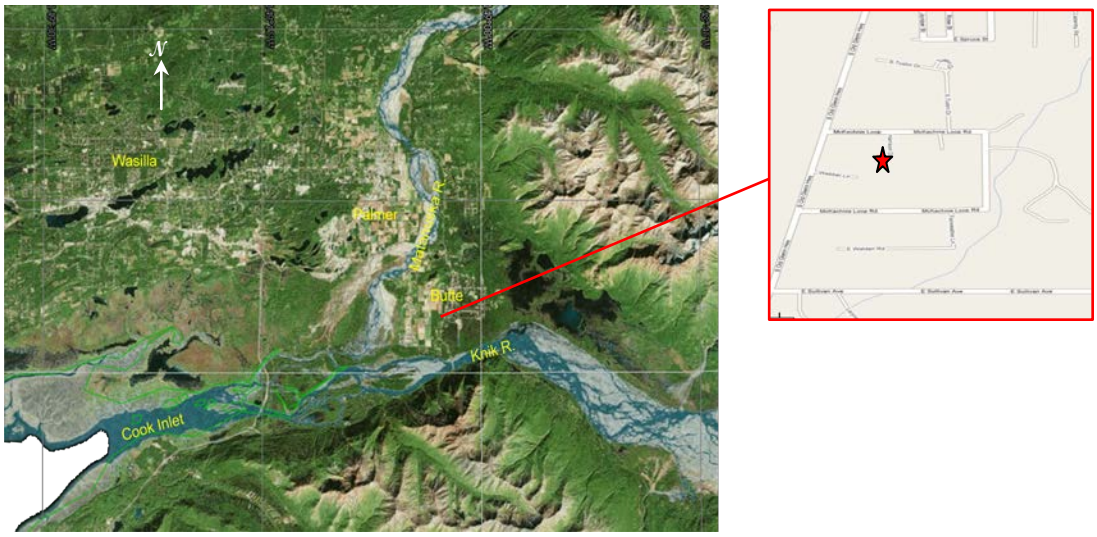


Figure 1. Topographic map showing location of Butte site in Matanuska-Susitna Valley (courtesy of http://www.gina.alaska.edu/data/)

The Butte is an unincorporated community of some 2,500 people located between the Matanuska River and the Knik River within the Matanuska-Susitna (Mat-Su) Borough, approximately five miles southeast of Palmer along the Old Glenn Highway (Figure 1).

ADEC began monitoring ambient air quality in the Palmer/Butte area in summer 1985 in response to smoke generated by fires used to clear land at Point Mackenzie, across Cook Inlet from Anchorage. It located one of the smoke monitoring sites at the Palmer airport. Although the monitors did not detect smoke, there were several sampling days with heavy dust loads. At that time, dust was covered by the "rural fugitive dust" waiver, an EPA policy that acknowledged that dust was part of farming.

Dust became more of an issue and "rural fugitive dust" waivers became fewer and fewer after the 1987 revision of the particulate standard from TSP to PM_{10}. By the early 1990s, dust had become a bigger issue nationally and Valley complaints about dust in the Butte/Palmer area had increased. ADEC ran a two-year, spring through fall air monitoring project in the Palmer/Butte area using non-FRM samplers developed by the Lane Regional Air Pollution Control Agency (LRAPCA). ADEC sited these light, easy to deploy samplers along the Old Palmer Highway from the Knik River Bridge to the Palmer Airport. The sampling results validated what the public had been saying: high dust levels occurred in spring and fall. The study identified the Matanuska and Knik river drainages, local farming, and local gravel pits as the main dust sources. The study also identified the mechanism for dust transport to be the strong, seasonal winds known as the Matanuska and Knik winds.

ADEC then established a fixed, special purpose monitoring (SPM) site at the Pioneer Peak Baptist Church on the Palmer Highway in Butte to continue the dust monitoring in the zone of maximum impact. ADEC began working with Mat-Su Borough staff in Palmer on a public

awareness campaign and notification system at the same time as they set up the SPM at the church. ADEC moved the monitor to its present location on Harrison Court in 1998. The samplers are in a portable trailer located at the end of Harrison Court, a short cul-de-sac less than one half mile east of the Old Glenn Highway and near the mouths of both rivers (Figure 1). Two small gravel airstrips, a dirt-track motor raceway, many acres of farmland, and recreation areas lie within five miles of the monitoring site. Most of the remaining undeveloped land in the area is forest.

The Harrison Court (Butte) site is currently a State & Local Air Monitoring Station (SLAMS). It is one of a network of over 4,000 similar monitoring sites throughout the nation. The current complement of samplers there includes a pair of Partisol 2000 samplers set up to measure $PM_{2.5}$ and $PM_{10,}$ and a coarse BAM pair comprising one PM_{10} BAM and one $PM_{2.5}$ BAM linked to calculate $PM_{10\text{-}2.5}$. In the past, ADEC has used an Anderson Hi-Vol to sample for PM_{10}.

Figure 2. View to the south at the Butte monitoring site on Harrison Ct. Left view taken on June 23, 1998 when PM_{10} level was 15 µg/m³, right view taken on May 15, 1998 when PM_{10} level was 587 µg/m³.

Much of the PM_{10} at the Butte site is fine, wind-borne silt (loess) from the bars in the braided rivers draining from the Matanuska and Knik Glaciers and from the outwash plains below them. This is an area of active loess deposition and the fine-silt fraction (20 µm to 2 µm) can be carried at least as far as 25 km from its source (Muhs et al, 2004; Rieger and Juve, 1961; Trainer, 1961; Tuck, 1938).

Steep pressure gradients over south-central Alaska, in combination with cold, dense air masses over the glaciers, create strong down slope (katabatic) winds that align parallel to the glacial river valleys. These so-called Matanuska and Knik winds are intermittent events. Matanuska winds blow from the north/northeast, typically occur in winter, and can last for several days. Knik winds blow from the south/southeast, typically occur in spring and late summer/fall, and are gustier and less prolonged (Dale, 1956). If these winds occur when low river levels expose large gravel bars and tidal flats and if conditions are dry, as is typical in fall and spring, large amounts of glacial silt are stirred up, entrained, and carried down the valleys by the winds (Figure 2). The Mat-Su Borough issues several air quality alerts per year because of these wind-blown dust events.

While ADEC began the monitoring at Butte for dust, it added $PM_{2.5}$ monitoring in 1999 in response to a new standard for $PM_{2.5}$ set by EPA. It continued to monitor for both PM_{10} and $PM_{2.5}$ using non-continuous, FRM type samplers; added a continuous, FEM type sampler for $PM_{10;}$ and, in summer 2011, installed a pair of continuous, FEM type samplers to monitor for $PM_{10\text{-}2.5}$.

Wood smoke in the area arises from local home heating in winter and intermittent forest fires in Interior Alaska, the Yukon Territory, and northwest British Columbia in summer. The residences adjacent to the monitoring site burn wood for winter home heating and, occasionally, burn trash outdoors in burn barrels.

PM_{10} Results

PM_{10} levels at Butte have exceeded the National Ambient Air Quality Standard (NAAQS) of 150 ug/m^3 nine times between April 1998 and December 2010 (Table 2). All nine occurred during high wind events and the highest value recorded was 605 µg/m³ in 2004. In addition to the dates of exceedances and concentrations, Table 2 lists Palmer airport wind sensor data obtained from the National Climate Data Center's NNDC Climate Data Online web application.[10] The data set is limited to wind observations taken on the hour rather than continuously. Therefore, it is possible that the "true" maximum wind speeds and directions are not all reported. However, the available data are useful in that they show a distinct pattern of high winds from the south/southeast in spring and fall (Knik winds) and from the north/northeast in winter (Matanuska winds). They also show that these local, well-known wind events occurred on the dates on which samples showed high $PM_{2.5}$ concentrations.

Table 2. Exceedances of PM_{10} NAAQS and wind data 1998-2010 at Butte, AK.

Date			Concentration	Max wind speed*	Direction
mo	day	yr	µg/m³	knots (mph)	
Apr	26	1998	220	11-15 (13-17)	SE
May	17	1998	180	16-20 (18-23)	SE
May	9	1999	161	21-25 (24-29)	SSE
Sep	21	2000	184	26-30 (30-35)	SE
May	9	2003	265	26-3 (30-35)0	SE
Apr	27	2004	605	21-25 (24-29)	SE
Apr	22	2005	176	31-35 (36-40)	SE
Dec	2	2007	168	31-35 (36-40)	NNE
May	12	2008	233	26-30 (30-35)	SE

*Wind data from Palmer airport sensor, data collected on the hour

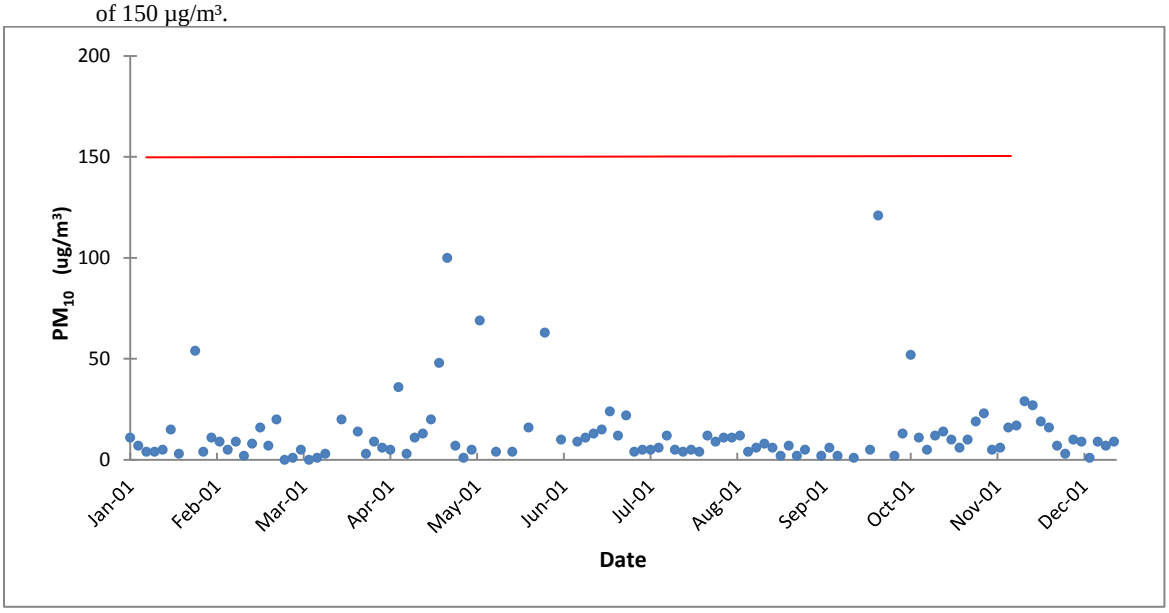
[10] http://www7.ncdc.noaa.gov/CDO/cdo

Table 3. Summary statistics of PM_{10} 24-hour averages at Butte, AK from 1999-2010.

Year	Mean µg/m³	Minimum µg/m³	1st Maximum µg/m³	2nd maximum µg/m³
1999	16	0	161	149
2000	12	0	184	125
2001	13	0	121	100
2002	9	0	37	36
2003	22	0	265	122
2004	29	0	605	97
2005	24	0	176	111
2006	14	1	84	79
2007	11	0	168	48
2008	16	0	233	87
2009	11	0	33	29
2010	11	0	49	45

Table 3 lists yearly averages, minima, and maxima from 1999 through 2010. Figure 3 shows the PM_{10} data collected at the Butte site during 2001. The data show a typical pattern of higher values in April/May and September/October. Data sets and similar graphs from the years 1999 through 2010 are in Appendix A.

Figure 3. PM_{10} 24-hour average concentrations in 2001 at Butte, Alaska. Red line is the NAAQS standard of 150 µg/m³.



$PM_{2.5}$ Results

Table 4. Summary statistics of $PM_{2.5}$ data at Butte, AK from 1999-2010.

Year	Annual 24-hr Mean µg/m³	Minimum µg/m³	1st Maximum µg/m³	2nd Maximum µg/m³	3rd Maximum µg/m³	Weighted Annual Mean µg/m³
1999	8	0.5	62.0	39.3	37.1	9.2
2000	6.1	0.8	30.1	30.0	27.8	6.1
2001	6.4	0.1	31.9	29.9	29.3	6.3
2002	5.6	0.3	40.0	36.7	34.6	5.6
2003	7.1	0.6	40.1	30.3	23.5	7.3
2004	7.8	0.3	27.5	23.3	20.3	7.8
2005	6.5	0.6	45.0	25.2	25.2	6.5
2006	7.4	0	48.6	40.0	39.4	7.5
2007	5.4	0	32.7	25.7	20.1	5.5
2008	6.2	0.5	35.2	33.0	30.8	6.2
2009	7.0	0	36.3	28.8	28.6	7.8
2010	6.9	1	42.5	38.4	37.5	7.5

EPA changed the $PM_{2.5}$ 24-hour NAAQS from 65 µg/m^3 to 35 µg/m^3 in 2006. It left the NAAQS for the annual mean at 15 µg/m³. Table 4 lists yearly averages, minima, and maxima from 1999 through 2010. Tables 5 and 6 list the design values as calculated by AQS. Annual and 24-hour $PM_{2.5}$ design values from 1999 through 2009 were below the NAAQS. However, some years did not meet the minimum data capture criteria of 75%. Design values within five percent of the NAAQS trigger daily monitoring.

Table 5. $PM_{2.5}$ 24-hour design values at Butte, AK from 1999 through 2010. All values are concentrations in µg/m³.

98th %	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	NAAQS
39.3[2]	1999	*39*[1]												65
27.8	2000		*34*[1]											
29.3	2001			32										
34.6	2002				31									
30.3	2003					31								
27.5[2]	2004						*31*							
25.2	2005							*28*						
40.0[2]	2006								*31*					35
20.1	2007									28				
30.8	2008										30			
28.8[2]	2009											*27*		
37.5[2]	2010												*32*	

[1] Number of years in the average < 3

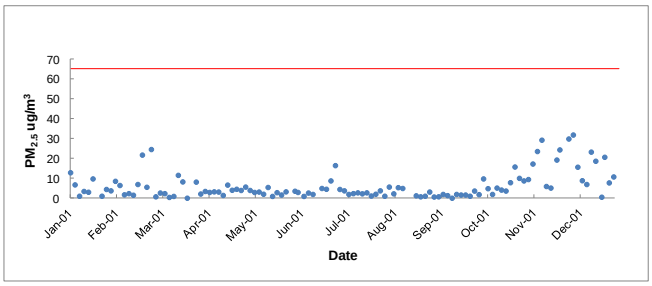
[2] Did not meet the minimum annual capture rate.

Table 6. $PM_{2.5}$ annual design values at Butte, Alaska, from 1999 through 2010. All values are concentrations in µg/m³.

Mean*	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	NAAQS
8.0	1999	*8.0*[1]												15
6.1	2000		*7.0*[1]											
6.3	2001			*6.8*										
5.6	2002				6.0									
7.3	2003					6.4								
7.8[2]	2004						*6.9*							
6.5	2005							*7.2*						
7.5[2]	2006								*7.3*					
5.5	2007									*6.5*				
6.2	2008										*6.4*			
7.8[2]	2009											*6.5*		
7.5[2]	2010												*7.2*	

*Mean = weighted annual mean
[1] Number of years in the average < 3
[2] Did not meet the minimum annual capture rate.

Figure 4. $PM_{2.5}$ 24-hour averages at Butte, AK in 2001.



The annual design values from 1999 through 2010 are well below the NAAQS of 15 µg/m³. The 24-hour design values for the same time period approach 33 µg/m^3 – the point at which daily monitoring would be required. However, ADEC is not sure if the $PM_{2.5}$ levels measured represent only the immediate area or if they represent Butte as a whole. ADEC picked the current site location as representative of PM_{10} levels and not necessarily as representative of $PM_{2.5}$ levels.

In general, $PM_{2.5}$ concentrations are higher during the late fall to early spring when the use of wood stoves for heating homes and when auto cold-starts and idling are common. The 2000 U.S. Census estimated that 45.8% of Butte households heated with natural gas, 38.8% heated with fuel oil/kerosene, and only 8.8% with wood. The 2010 U.S. Census did not gather this level of detail on home heating sources for this area. Summer concentrations are lower except for spikes caused by drifting smoke from wildfires and intentional slash burns. Figure 4 is a typical annual graph of $PM_{2.5}$ concentrations. $PM_{2.5}$ data and graphs for 1999 through 2010 are included in Appendix B.

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